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ABSTRACT

Although color vision deficiency is a prevalent problem in childhood, little is known about the cognitive and social-emotional variables linked to this difficulty. A review of the literature revealed seven empirical articles exploring the psychological functioning of color-deficient children, with the results yielding contradictory findings. The equivocal nature of past research is believed due to two research weaknesses: inadequate theoretical rationale of the outcome variable to be linked to color deficiency; and lack of internal validity, which is manifest in faulty designs and poor assessment instruments. An investigative protocol is recommended to minimize research difficulties and lead to a more accurate psychological description of the color-deficient child. The protocol recommended is structured around the initial two sections of an empirically based study: introduction and methods. An ideal introduction would consist of a theoretical rationale emphasizing why color deficiency should be associated with certain cognitive and social-emotional variables and would indicate what measures can be used to determine differences between children with low functional vision compared to adequate functional vision. Recommended methods include use of the anomaloscope and use of pre-group equating to reduce the source of possible confounds. (19 references) (Author/JDD)

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The Cognitive and Social-Emotional Correlates of Color Deficiency in Children

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Paper presented at the 1990 Annual Meeting of the Arizona Educational Research Organization/Rocky Mountain Educational Research Association. Phoenix, AZ.

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Abstract

Although color deficiency is a prevalent problem in childhood, little is known about the cognitive and social-emotional variables linked to this difficulty. In fact, a review of the literature revealed seven empirical articles designed to explore the psychological functioning of color deficient children, with the results yielding contradictory findings. The equivocal nature of past research is believed due to two notable research weaknesses, specifically (a) inadequate theoretical rationale of the outcome variable to be linked to color deficiency, and (b) lack of internal validity, which is manifest in faulty designs and poor assessment instruments. These weaknesses are to some extent remediable, and as a means towards that end, an investigative protocol is recommended which may minimize previous research difficulties, and lead to a more accurate psychological description of the color deficient child.

Introduction

Color deficiency is defined by Litton (1979) as, "a confusion of, or blindness, to one or more of the chromatic colors....it is any condition that in some way limits a person's ability to distinguish one color from another, or different shades of the same color" (p. 438). It is common to here of subtypes of color deficiency. The most severe form of color deficiency, and rarest, is monochromatism, which is seeing no chromatic colors. Two other subtypes are deuteranomaly, a confusion of at the green end of the color spectrum, and protanomaly which is confusing red with other colors.

Considering that roughly eight percent of elementary school children are diagnosed as color deficient (Sewell, 1983), it is amazing that so little is known about the cognitive and social-emotional correlates of color deficiency in childhood. What little research is available is predominately equivocal, especially with regard to cognitive functioning. Thus, the purpose of this review is to (a) better understand color deficient children presenting research findings on their typical pattern of cognitive and social-emotional functioning, (b) explain previously contradictory findings in the context of two substantive research issues, and (c) suggest an ideal investigative protocol for further research in this area.

Review of the Literature

The literature reviewed was obtained through computer searches of the ERIC and PSYCHINFO databases. Computer searches were carefully planned through (a) use of the appropriate thesaurus and Boolean descripters to link research concepts (e.g. color deficiency and social development, etc.). As articles were retrieved the bibliographies were reviewed in order to select additional references. This resulted in a total of seven data based articles pertaining directly to the cognitive and social-emotional functioning of color deficient children. This literature is presented in Table 1 and will be discussed next.

Insert Table 1 About Here

Social-Emotional Functioning

Synder (1973) in an anecdotal report, suggests that color deficiency hinders the development of a normal self-concept, an analysis which seems intuitively reasonable. Amazingly, only two empirical studies were located which investigated the emotional characteristics of color deficient children. Cobb (1980) examined whether 11 fourth grade color deficient children differed from 11 normally sighted peers on the Extraversion-Introversion, and Neuroticism-Stability factors as measured by the Eysenck Personality Inventory. No differences between groups were found.

On the other hand, Espinda (1973), in a prevalence study, noted that color deficient children were more frequently placed in classrooms for emotionally handicapped than normally sighted children, a finding which suggests that color deficient children may have social-emotional deficits.

Cognitive Functioning

Five studies were found which examined the cognitive abilities of color deficient children. Three of these studies revealed that color deficient children are weaker in certain areas of cognition and school achievement. For example, Knowlton & Woo (1989) found that color deficient children made more errors on a visual-matching task than did non color deficient children. Dannenmaier (1972) found that color deficient high school students received lower course grades in a beginning Biology than did a non color deficient comparison group. Shearron (1964) noted that color deficient children have lower reading achievement scores than non color deficient children.

Yet, studies by Lampe, Doster, and Beal (1973), and even other data collected by Shearron (1964) reveal that color deficient children either do not differ, or in fact, exceed non color deficient children in the areas of intelligence and achievement. For example, Shearron (1964) found that first color deficient children have higher measured intelligence than did a non color deficient comparison group. Lampe, Doster, and Beal's (1973) data showed no difference in achievement between color deficient children and their non color deficient counterparts. Also, in a prevalence study, Litton (1979) noted that color deficient children were no more prevalent (14 percent) among Learning Disabled students than students enrolled in regular classes (5 percent).

In sum, the research examining the social-emotional and cognitive correlates of color deficiency in children is contradictory. Obviously, a consistent picture of the color deficient child's cognitive and social-emotional characteristics has yet to emerge.

A close inspection of the available studies reveals that methodological problems may explain why the results are equivocal. In fact, the seven data based studies reviewed reveal a confusing mixture of rationales, methods, and assessment procedures. The latter two issues will be discusses as issues of internal validity.

Investigative Caveats

Use of Theory to Guide Research

Researchers in this area tend to neglect the theoretical context and rationale for why color deficiency in children should be associated with certain cognitive and social-emotional characteristics. The link itself cannot be any stronger than that found in the reviewed studies, which is something like...."color deficiency makes children different...these differences affect the way color deficient children interact with the world.....therefore, color deficiency should lead to differences in the area of cognition and emotion." As one example, Cobb (1980) introduces the purpose of his study as follows..."the possession of red/green color defects must necessarily cause some confusions in perception in addition to practical problems. It may also affect other people's reactions towards him....(p. 159) (my emphasis). In the area of cognition, the link is supported by the obvious fact that color deficient children will necessarily suffer when learning materials are color coded (e.g. Words-in-Color, Sullivan Programmed Primer), and therefore, intelligence, achievement, and emotional development may also be adversely affected. This logic is used by Dannenmaier, (1972), Lampe, Doster, Beal (1964), Litton, (1979), and Knowlton & Woo (1989).

The above rationale is sufficient only for making the link between color deficiency and some cognitive and emotional process. It is insufficient in terms of explaining what outcome variables should be tied to color deficiency. In other words, what is needed is a stronger theoretical rationale of the intellectual and social-emotional variables to be associated to color deficiency. What kind of cognitive, intellectual, or emotional function should be related to color deficiency and why? It is not enough to simply associate color deficiency with a variable easily obtained from a school file (e.g. intelligence, or achievement test score), because this is guessing, but not science (Kerlinger, 1986). On the other hand, when armed with well grounded theories of color deficiency and of cognitive and social-emotional functioning (e.g. Piaget, Erickson, Bruner, Murray), investigators will have more reason to make stronger predictions from theory, and more reason to believe that the results will confirm these predictions.

Internal Validity

In general, researchers conceive of color deficiency as an independent variable which is hypothesized to explain various differences in some outcome measure. In this case, the issue of internal validity is the extent to which color deficiency actually causes children to differ from their normally sighted counterparts (between groups comparisons) in cognitive and social-emotional functioning. Internal validity is a complex concept affected by a number of factors, many of which can be controlled by true experimental designs. Unfortunately, because color deficiency is an attribute variable that cannot be experimentally manipulated, and therefore, randomization cannot occur, the internal validity of this type of research can never be considered as good as that of a true experiment. However, even when researchers study attribute variables, procedures can be implemented to equate for potentially confounding

variables (e.g. matching), in order to reduce the likelihood that competing explanations can account for the observed results. Reducing the potential for confounding is clearly lacking in this area of research, and this is one way in which internal validity is compromised. The second internal validity concern is the lack of sound psychometric instruments to measure color deficiency, an issue which compromises the actual meaning of the color deficiency construct. Each of these issues will be addressed next.

Research design. A brief review of the research designs reveal the following. Three of the studies reviewed (Dannenmaier, 1972; Espinda, 1973; Litton, 1979) were correlational in nature, since the primary focus was to relate color deficiency to grades, or placement in LD or EH classes. Dannenmaier (1972) used a Pearson R between color deficiency and grades in Biology, while Espinda (1973) and Litton (1979) employed chi-square to examine the frequencies of color deficient and normally sighted peers classified as EH or LD, or not EH or LD. Only Dannenmaier (1972) correlated color deficiency with intelligence (no relationship) in an attempt to rule out IQ as a competing explainer of the results.

Three other studies (Shearron, 1964; Lampe, Doster, & Beal, 1973; Cobb, 1980) focused on mean differences (a la t-tests) between color deficient children and normally sighted peers on various scales, such as the Eysenck measure, Metropolitan Achievement Test, and the Stanford Achievement Test. The consistent findings in these studies, as noted earlier, showed no significant differences between groups for all outcome measures. Only in the Lampe, Doster, and Beal (1973) study was intelligence ruled out as a possible confound, since a correlation of near zero was obtained.

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Knowlton & Woo (1989) utilized a 2 x 3 x 2 complex ANOVA design, considering color deficiency and non-color deficient children as one variable, but also examining three levels of contrast, two types of conditions (ditto or photocopy) as additional variables which might affect the matching task they used as their dependent variable. Subjects were matched by age and visual acuity.

With the exception of Knowlton & Woo's (1989) visual matching task, the remaining dependent variables were incidence in LD or EH classrooms, achievement functioning (grades, or scores on achievement tests) and two scales of Eysenck's Personality Inventory. Clearly, achievement and personality functioning are a function of countless other variables, both demographic (e.g. SES, ethnicity, age, gender) and psychological (e.g. motivation, attribution, intelligence, self-concept). The implication is that before studying between group differences in outcome measures like school achievement the groups should be equated prior to study in order to reduce the likelihood that other variables can account for the differences in the dependent variable.

In this area, some of the demographic variables do not seem to be competing explainers. For instance, age is naturally restricted in this research because only one grade, or age group is evaluated (with the exception of Knowlton & Woo, 1989). Color deficiency is almost always a male deficit, so there is a natural restriction here as well. Of course, it cannot be assumed that the cognitive and social-emotional functioning will be equal for color deficient children of different ages, or across gender. These issues are clearly in need of further study. SES appears to be a potential confound, since Shearron (1964) found to be different between color deficient (lower) and non color-deficient groups. No study has equated groups on this factor.

Most of the psychological confounds are unexplored. Dannenmaier (1972) and Lampe, Doster, & Beal (1973) correlated total scores on an intelligence test with the color deficiency assessment score, and both found non-significant correlations. This means that the color deficient and non-color deficient groups appear equal on this potential confound, and therefore, may not need pre-group equating prior to study.

Interestingly, matching on variables prior to studying ex post facto differences in groups, assumes that the variable being matched actually differs between groups. Yet, because so little data exists in this area, it is difficult to determine exactly what variables differ between color deficient and non-color deficient groups. Self-concept, attributions, motivation, ethnicity are just some of the examples which have yet to be researched. Clearly, this type of research is needed in the future.

Also, it is odd that all of the research reviewed centers on between group comparisons. What is unexplored is the cognitive and emotional heterogeneity of the color deficiency group. This type of research could identify perhaps intra-group differences in self-concept, than dichotomize (or trichotomize) the color deficient groups into say three levels of self-concept (low middle, and high), than look for potential reasons for this type of group difference (e.g. parenting style, support groups, social skills, etc.). This type of research would have tremendous practical implications, and is clearly warranted in the future.

Assessment of the color deficiency construct. A particularly troublesome issue for researchers is accurately assessing color deficiency. Because of this difficulty, the color deficiency construct is difficult to operationally define, and thus, even when a relationship or difference is found for an outcome variable, it is unclear whether this result was due to the color weakness attribute.

The assessment of color deficiency in six of the seven reviewed studies (with the exception of Knowlton & Woo, 1989) was done via some type of pseudo-isochromatic plates (Dvorine, 1953; Hardy, Rand, & Ritter, 1957; Ishihara, 1970), where subjects were asked to identify a number embedded in a contrasting color. However, pseudo-isochromatic plates appear particularly troublesome in terms of test-retest reliability and criterion validity. For instance, Perales, Hita, Jimenez del Barco & Romero (1984) found that when using the Ishihara plates almost 20 percent of their color deficient group changed classification (either from color deficient to non color deficient, or major to minor color deficiency) at the retest interval.

As for criterion validity, Salvia & Ysseldyke (1971) examined the degree to which three different pseudo-isochromatic plates compared in frequency of identification of color deficiency with a criterion measure (an anomaloscope) for 90 mentally retarded subjects. They found that median correlation between the pseudo-isochromatic plates and the anomaloscope was only .60, and the median percent of false positives across all three instruments was a whopping 58 percent. They added that the plates were invalid for diagnostic purposes.

These results render past research questionable at best. Since researchers assessing color deficiency have predominately used pseudo-isochromatic plates, there is no certainty that the color deficiency group does not consist of many non-color deficient children and vice versa. In addition, the above research calls into question the stability of the color deficiency construct as presently assessed in research studies.

Indeed, Knowlton & Woo (1989) have entirely reconceptualized the color deficiency construct as functional vision which combines color deficiency with other visual skills (acuity, and contrast) and have devised a new assessment process which reportedly measures functional vision (although no reliability and validity data were reported in their study). If their analyses prove valid, then color deficiency, as previously defined, cannot be considered an adequate representation of the construct.

Investigative Protocol for Future Research

Based on identified research concerns, the following section is devoted to recommendations for improving research aimed at determining the cognitive and social-emotional correlates of color deficiency. The investigative protocol recommended is structured around the initial two sections of an empirically based study--introduction, and methods.

Introduction

An ideal introduction would consist of a theoretical rationale regarding both the color deficiency and cognitive and/or social-emotional constructs. The theoretical discussion would emphasize why color deficiency should be associated with certain cognitive and social-emotional variables. Further, the theoretical approach selected should form the foundation for a clear research question and associated hypotheses. One potential example follows.

Knowlton & Woo (1989) suggest that color deficiency is just one aspect of a multi-faceted visual construct, one they named functional vision. This position theoretically founded in the tradition of empiricism, where objects are said to have a number of perceivable properties, such as hue, color, distance, shape, etc. (cf. Bornstein, 1985). It could be argued then, that color deficiency per se, is just one component of several which comprise functional vision, and, in fact, the contradictory results of previous literature may be due to the inadequate conceptualization of the color deficiency construct. If this is correct, then it no longer makes sense to isolate color deficiency as the focus of research, but instead to examine the degree to which children with low functional vision differ from children with adequate functional vision.

The next step is to determine on what types of measures should low functional vision theoretically differ from children with adequate functional vision. One potentially relevant theory would be Henry Murray's (1938), especially the types of needs which may be present in low functional vision children. For instance, the need for autonomy may be greater in low vision children on the assumption that significant others will help the low vision children complete tasks of daily living, such as dressing, and therefore, increase the need to be autonomous. Indeed, all of Murray's needs may hypothetically differ between low functional vision and adequate functional vision children. The point here is to use a theory of the outcome variable to make stronger predictions about the nature of the differences between children with different levels of visual skill.

Method

The internal validity issues--research design and assessment--will be discussed in this section. Research design is mentioned in the context of a design subsection, while assessment is noted in an instruments subheading.

Instruments. Concerns about the psychometric properties of pseudo-isochromatic plates preclude their diagnostic utility, and thus should not be used for research purposes. According to Salvia & Ysseldyke (1971) and Alexander (1975) the anomaloscope is the only instrument possessing sufficient psychometric qualities. Since the anomaloscope measures brightness contrast and color, it is also more suited to the definition of functional vision proposed in the introduction. The assessment procedure described by Knowlton, Sorenson, & Grafsgaard (1987) measures all functional vision skills--color, contrast, and acuity--and may be even more adequate than the anomaloscope, although their procedure is in need of documentation of psychometric properties. At present, the anomaloscope is the recommended assessment instrument.

Design. Visual skill is an attribute variable, and as such, can be examined only via ex post facto research; that is designs where low versus adequate and/or superior functional vision will define the independent variable groups. The key design component is the inclusion of some type or pre-group equating to reduce the source of possible confounds. If the dependent variable is needs, then whatever factors influence needs (e.g. SES, ethnicity) should be equated between groups. If the dependent variable is to be factors on an IQ test, then school achievement should be equated between groups. The idea of incorporating possible confounds, such as SES into the design is not recommended, because the number of low functional vision subjects will be small to begin with, and further classification of this group into more levels will continue to reduce the number of subjects per experimental cell. For example, of the 80 low functional

vision children, 70 may be from lower SES families, which means the other division would only have ten subjects.

Summary and Conclusion

Equivocal findings exist regarding the cognitive and social-emotional correlates of color deficiency in children. The contradictory findings were explained as a function of (a) inadequate theoretical rational of the outcome variables supposedly linked to color deficiency, and (b) internal validity issues, specifically inadequate designs and the poor psychometric qualities of assessment instruments. Based on these concerns, an investigative protocol was recommended for further research.

It is hoped that researchers continue to explore the differences between children with different levels of visual skill and the effects of this deficit on various psychological variables. There is an appealing intuitive link between visual difficulty and cognitive and social-emotional variables, and this link is clearly in need of more systematic, thoughtful examination.

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Table 1

Review of Research Relating Color Deficiency to Cognitive and Social-Emotional Variables

Study	Sample	Assessment	Design	Results
Cobb (1980)	11 CD* and 11 non CD 4th year children	Ishihara Test of Color Blindness	Ex Post Facto (t-tests)	No significant differences between groups for extraversion or neuroticism
Dannenmaier (1972)	81 high school juniors/seniors who had completed a biology course	A-O H-R-R Plates	Correlational	Significant negative R (-.34) between errors on assessment test and Biology grades
Espinda (1973)	83 EH elementary school children and 139 regular education	Ishihara Test of Color Blindness	Correlational--Chi-Square	Significantly more EH children labeled CD than regular class children
Knowlton & Woo (1989)	16 visually impaired with CD and 16 visually impaired without CD subjects	Functional Vision Assessment	Complex ANOVA	No main effect for CD group Interaction of group x contrast (blue-purple group made more errors in ditto condition)

Study	Sample	Assessment	Design	Results
Lampe, Doster & Beal (1974)	74 to 80 CD children in first and second grade and 161 non CD children	Ishihara Test of Color Blindness	Ex post Facto (t-tests)	No significant differences between CD and non CD children on Stanford Achievement Test Scales--word meaning math computation, paragraph meaning, and word study skills
Litton (1979)	59 LD and 57 non LD ages 7 to 12.	Ishihara Test of Color Blindness	Correlational--Chi-Square	No significant difference in prevalence of CD in LD or non LD children
Shearron (1964)	35 CD children and 35 non CD children in first grade	A O H-R-R Plates	Ex Post Facto (t-tests)	CD children had higher IQs than non CD children CD children families have lower SES than non CD children Non CD children had higher reading achievement scores than CD children

*CD = Color deficient